Impact of different bias correction methods on the NH sea ice prediction in a set of seasonal forecast systems

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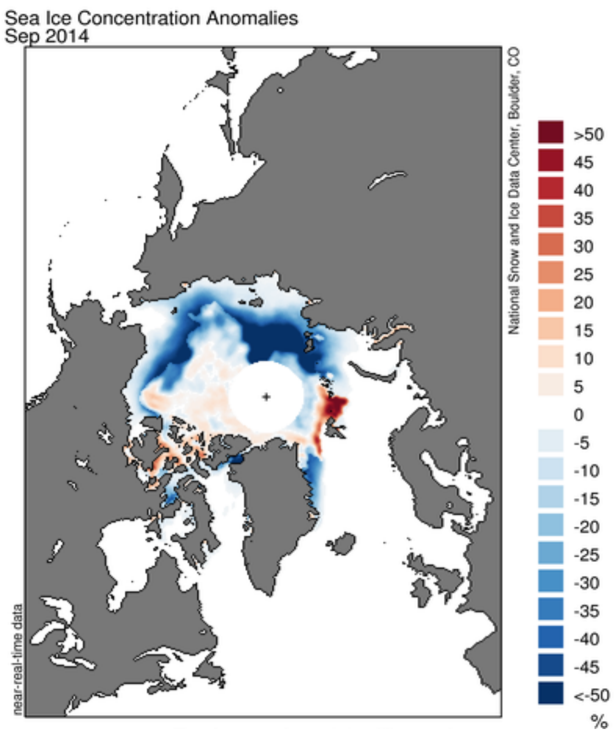
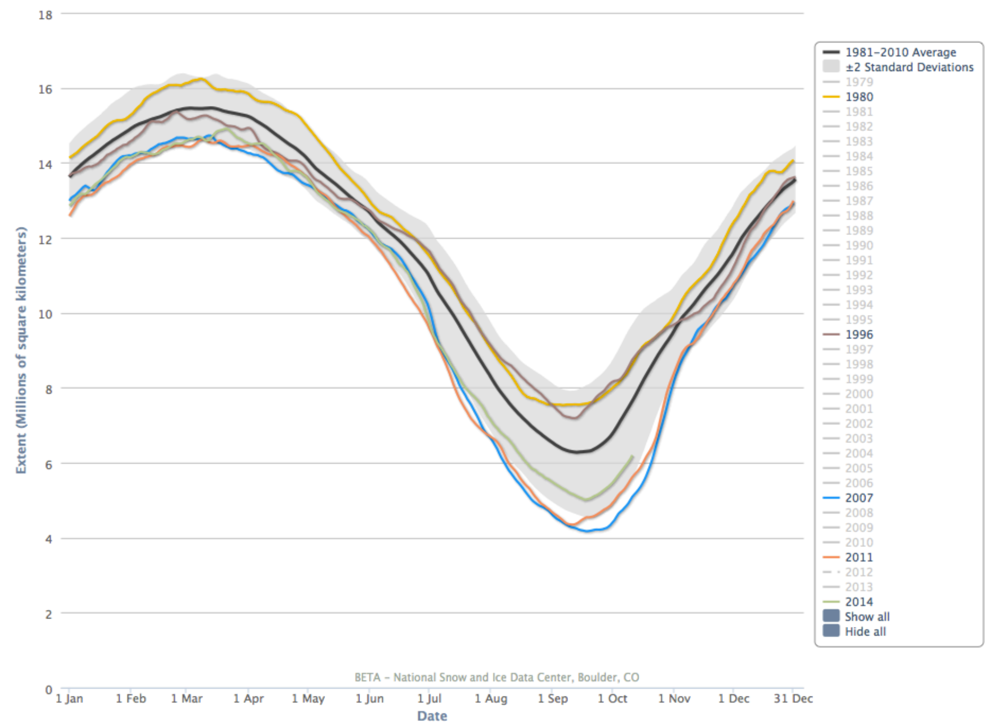


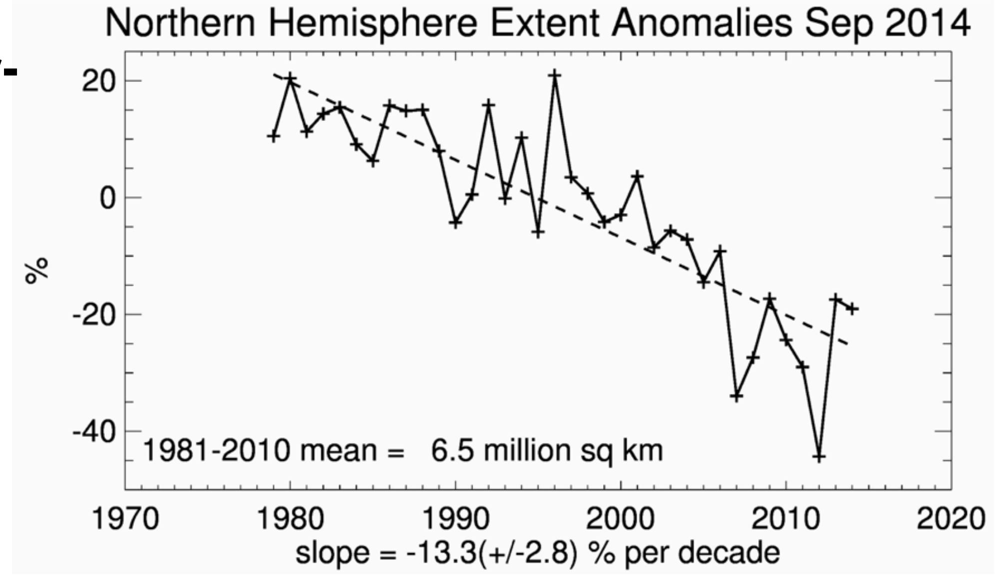


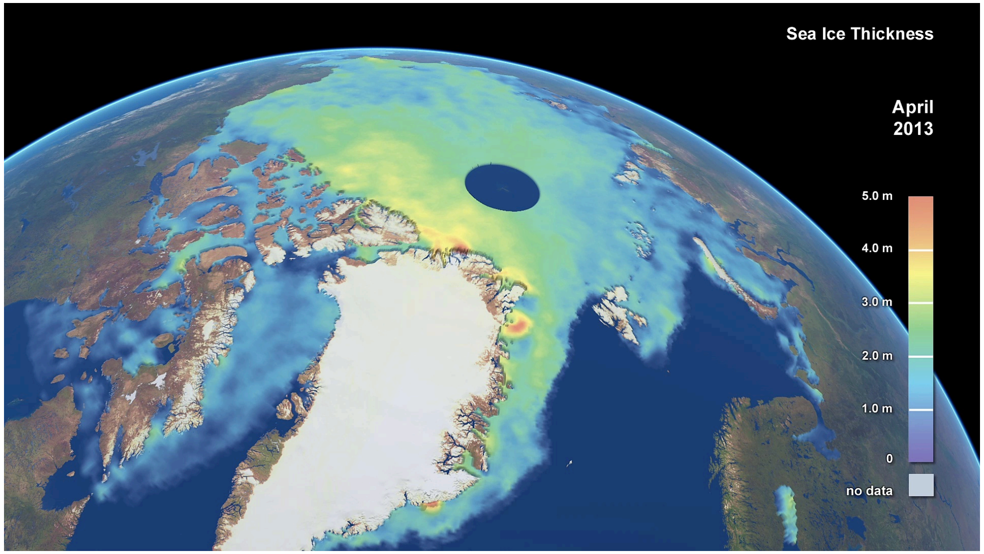
April 10, 11:00 Session 8 – Predictions III, at Sea Ice Prediction Workshop, University of Reading, Reading, UK, April 8-10, 2015

- **Introduction and forecasting systems**

Since 1970s Arctic sea ice cover is undergoing substantial reduction and thinning in every month (especially September)

→ multi-year sea ice is being replaced with first-year sea ice making summer sea ice cover more variable from year to year and near-term climate prediction more challenging





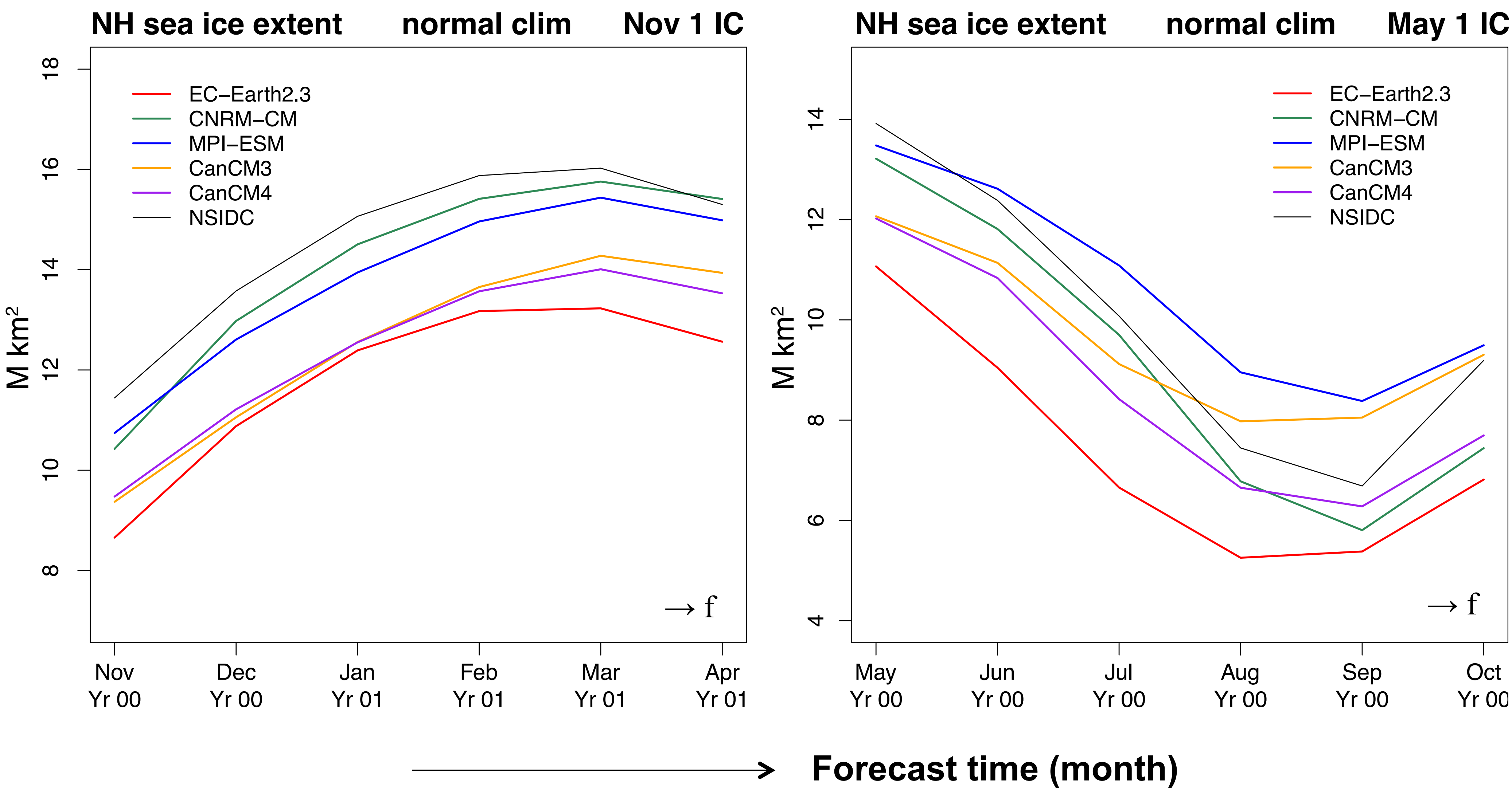
We use a set of coupled climate forecast systems with full-field initialization:

→ **EC-Earth2.3**
→ **CNRM-CM (a successor of CM5)**
→ **MPI-ESM**
→ **CanCM3 and CanCM4**

Soon to include GloSea5 and GFDL CM2.1 seasonal forecasts

Analyzed forecast systems typically underestimate sea ice extent climatology

⇒ we need to remove mean bias, but also address conditional drift dependence



• Hierarchy of bias correction methods (Fučkar et al., GRL 2014)

Even with the best possible forcing, BC and IC, model bias can be **>** climate signal of interest

1) Mean (per-pair) bias correction method

→ replaces the long-term mean (over start dates *i*) of a model variable with the long-term mean of corresponding obs at each forecast time *f* (or lead time *l*)

Some forecast systems, beside the mean bias, also exhibit a conditional bias in time, i.e., a forecast drift that is dependent on the start date or other physically more relevant information

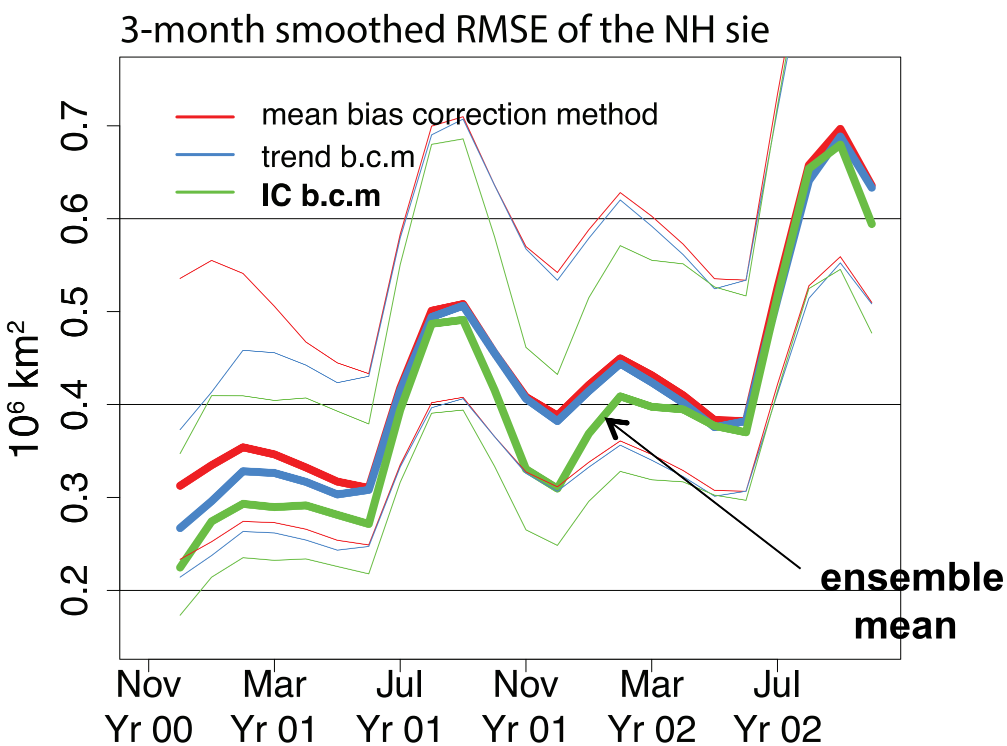
2) Trend bias correction method

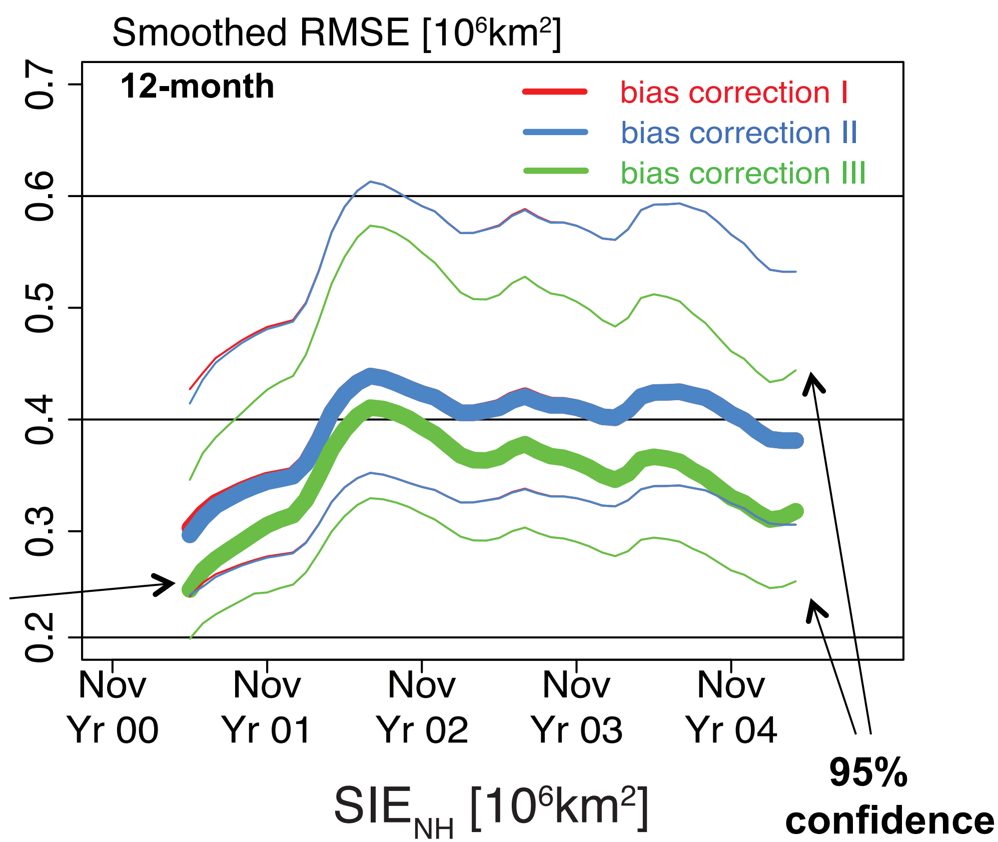
→ replaces a linear regression of the forecasts on *i* with the linear regression of the corresponding obs on *i* at each forecast or lead time

Trend bias correction can also account for difference between the forecasted and obs. long-term trends, but even if they are similar there can be drift dependence on IC due to internal variability

3) New IC bias correction method

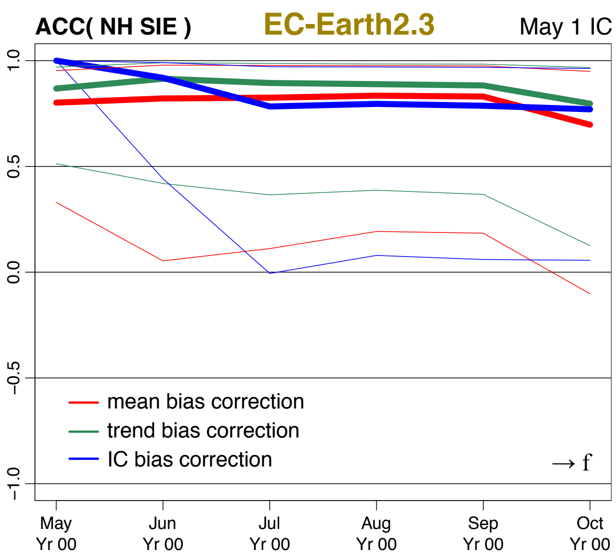
→ replaces a linear regression of monthly forecasts on OBS IC smoothed in time, e.g., obs in the first forecast month $o_{i,1}$, with the linear regression of monthly obs on $o_{i,1}$ for each forecast month *f*

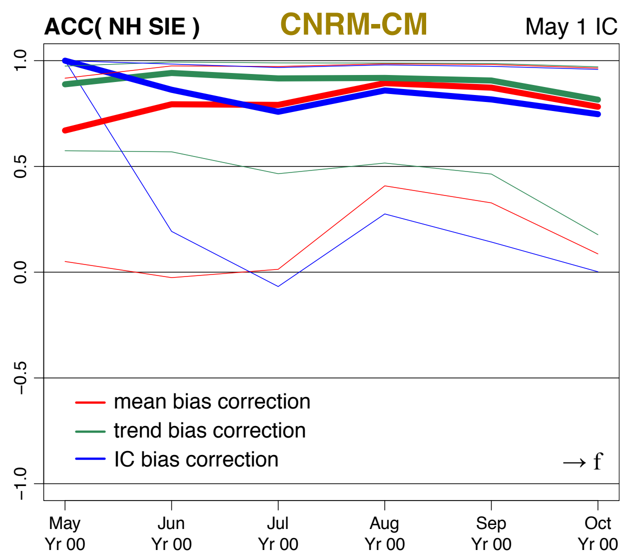


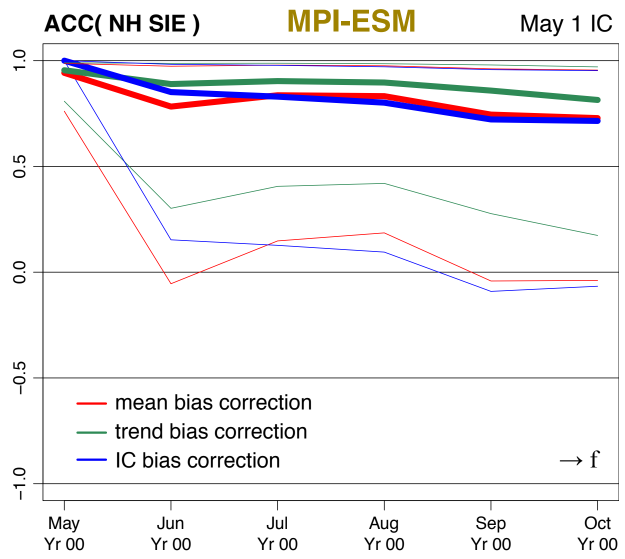


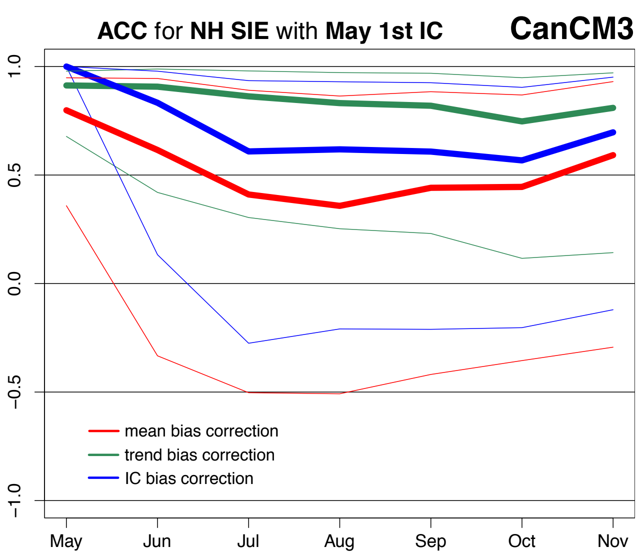
Instantaneous IC at the beginning of a month are too noisy for the application in climate forecast on monthly and longer time scales
⇒ we need to use a smoothed proxy of obs IC (multiple options)

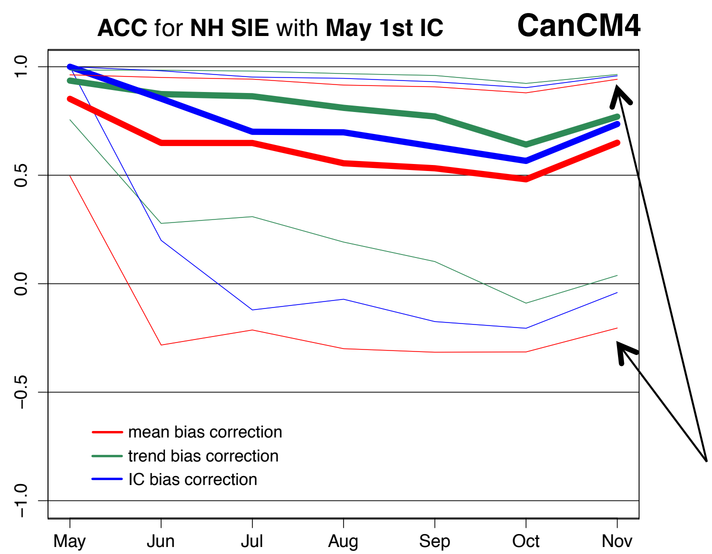
IC bias correction method has a strong sensitivity to the quality of obs ⇒ extending hindcast archive deeper into the past may not benefit the prediction skill (sparse and/or low quality obs), but with a shorter verification period we could increase the uncertainty







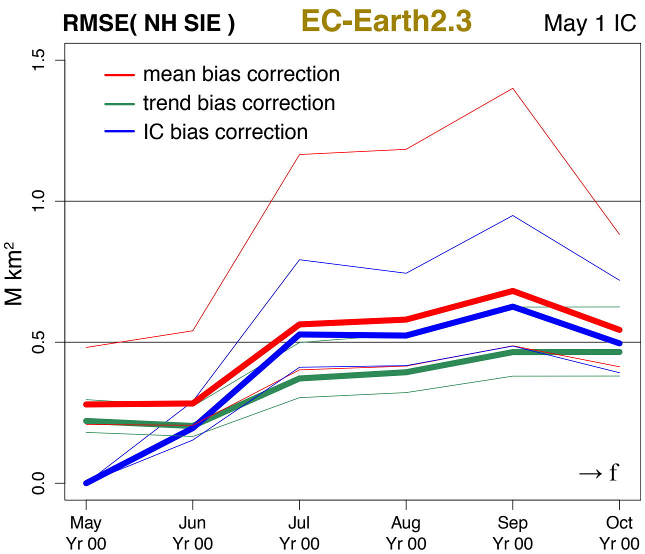


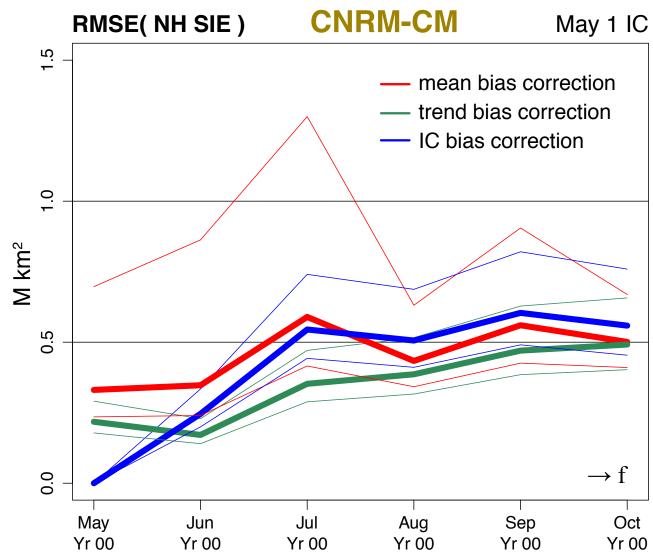


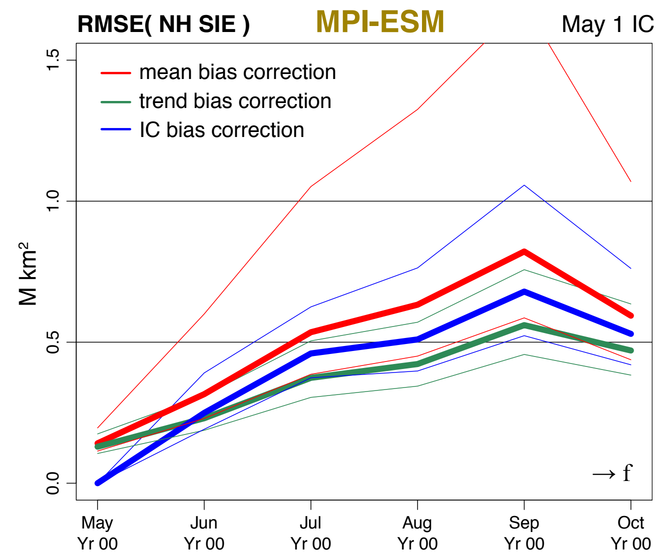
More sophisticated bias correction methods offer relevant but not statistically significant (95%) improvements over the mean (per-pair) adjustment method

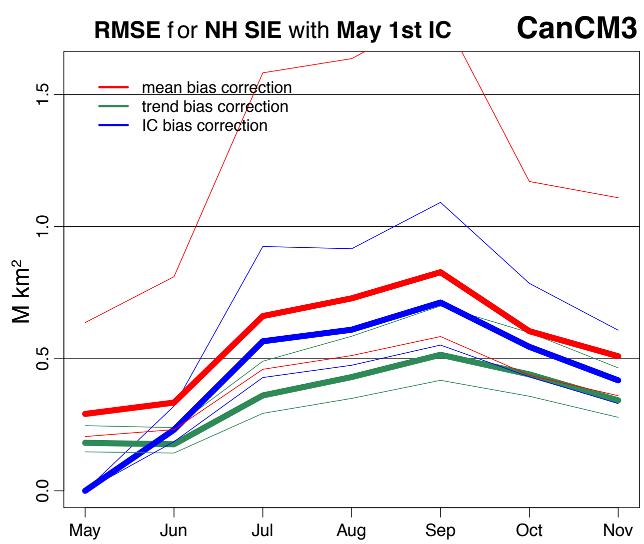
95% confidence interval

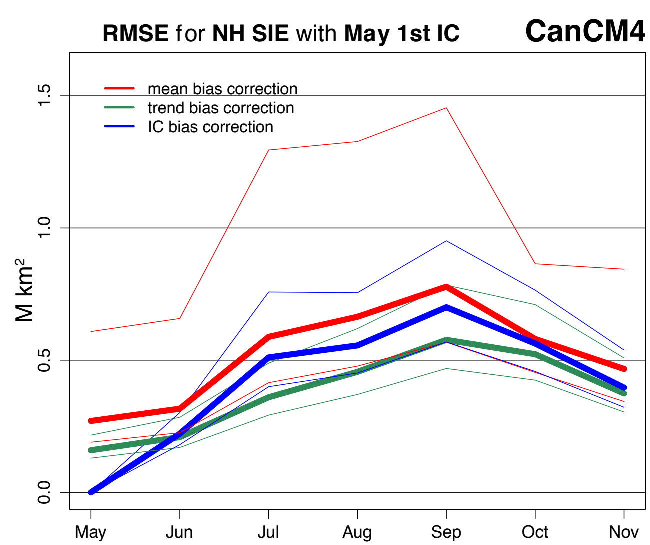
→ **Forecast time (month)**







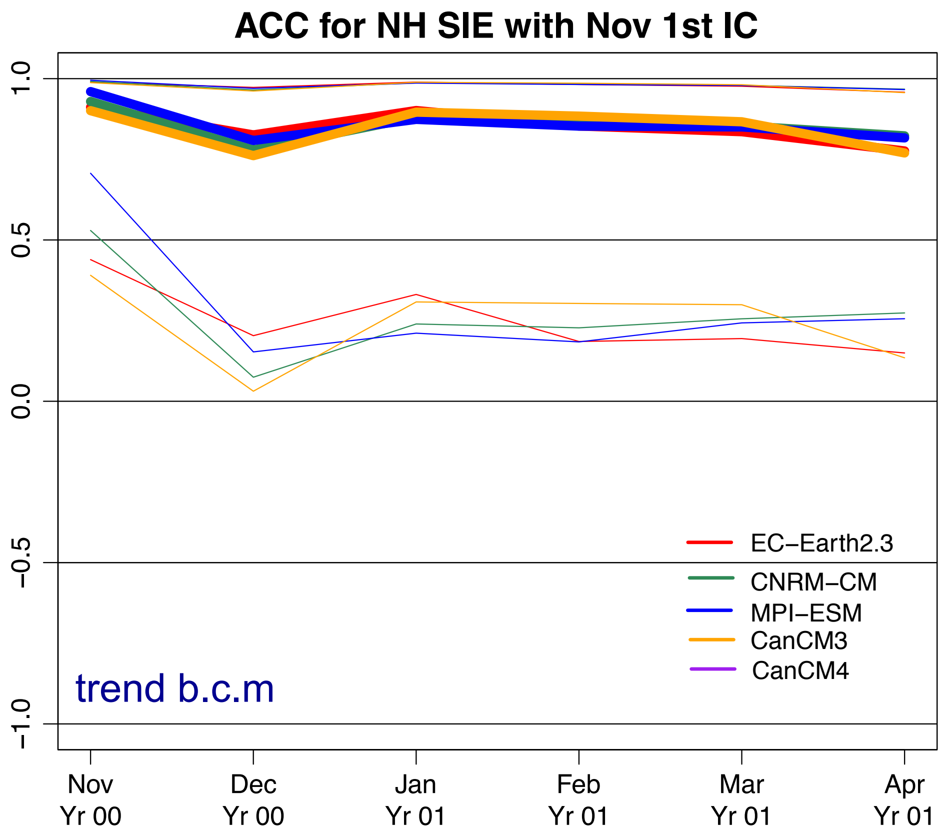


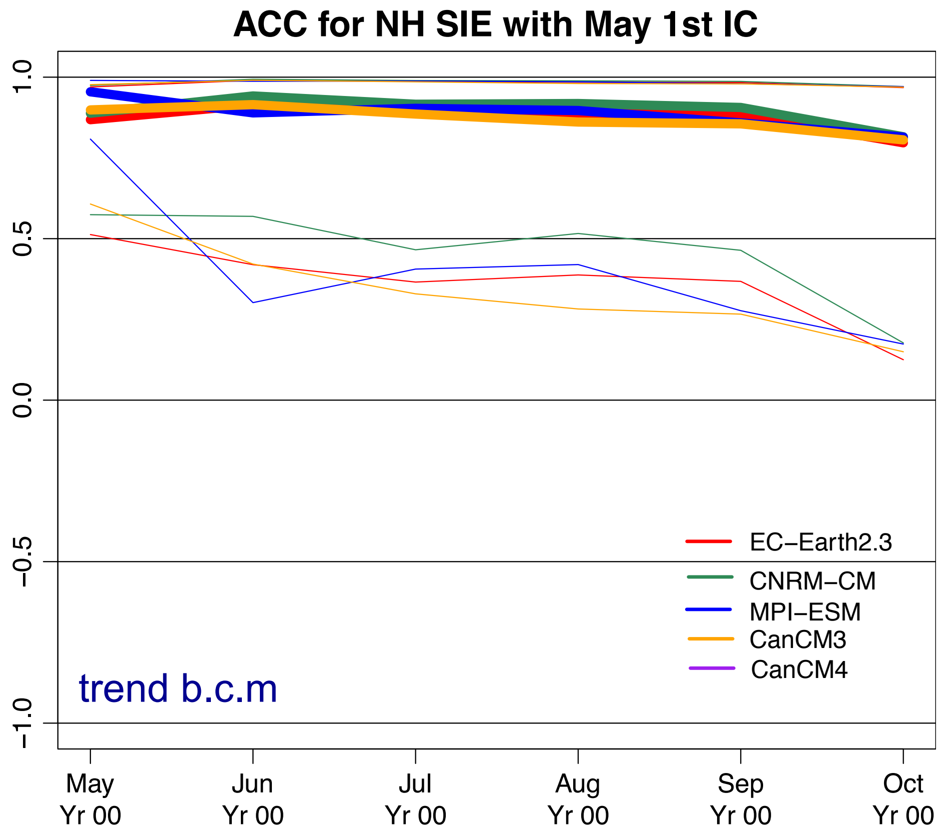


Trend bias correction method in analyzed models offers the most significant improvements in skill of the NH sea ice extent (SIE) in September likely due to significant errors in their long-term trends

→ **Forecast time (month)**

Trend bias correction method leads to convergence of ACC in all models ⇒ March and September are rather similar from point of anomaly correlation, but model errors …

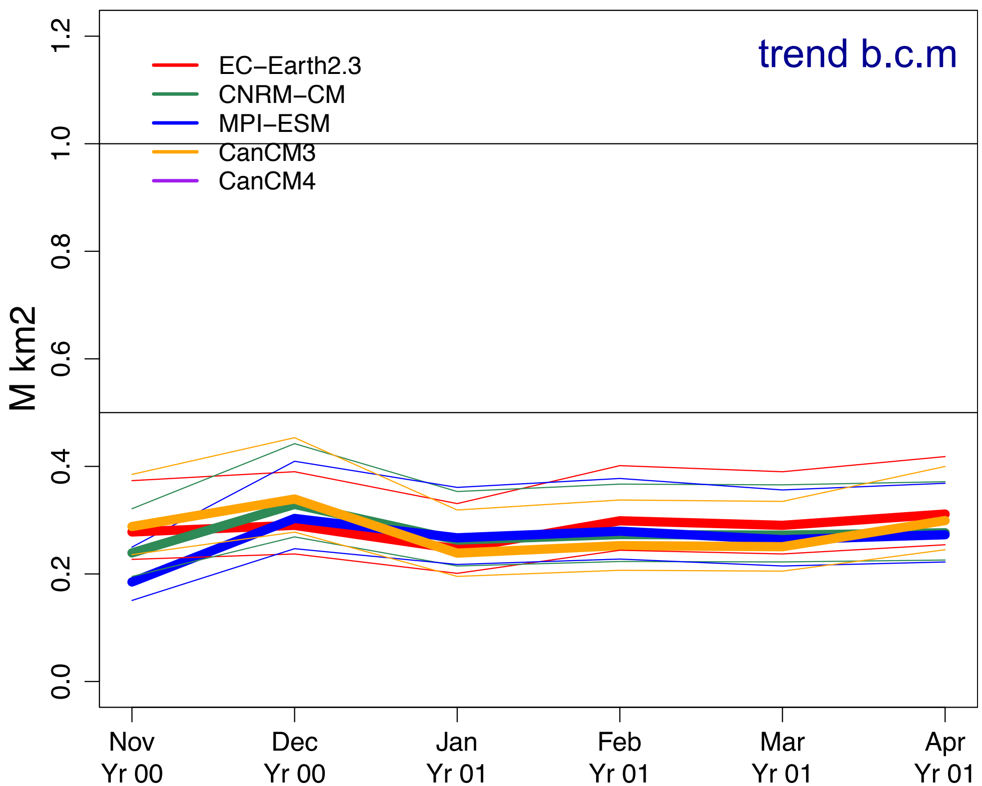




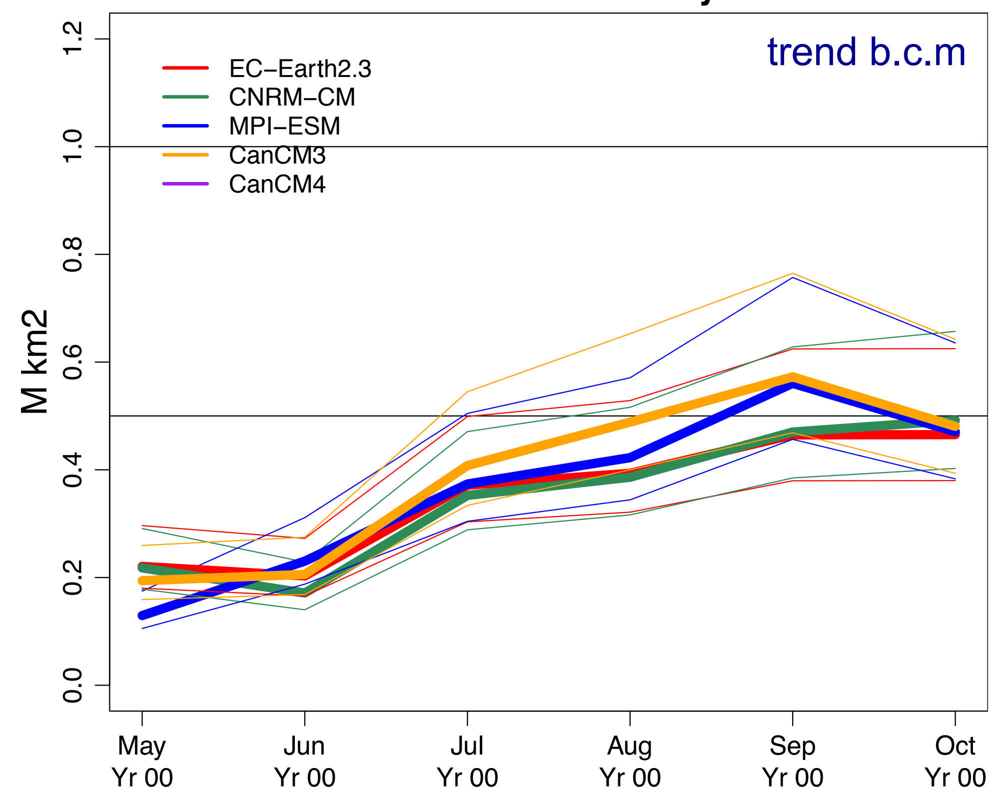
Forecast time (month)

Synoptic condition biases in summer and missing sea ice processes that can provide positive feedbacks (e.g., melt ponds, snow cover dynamics, etc.) are likely causing higher RMSE during boreal melting season than during boreal growing season

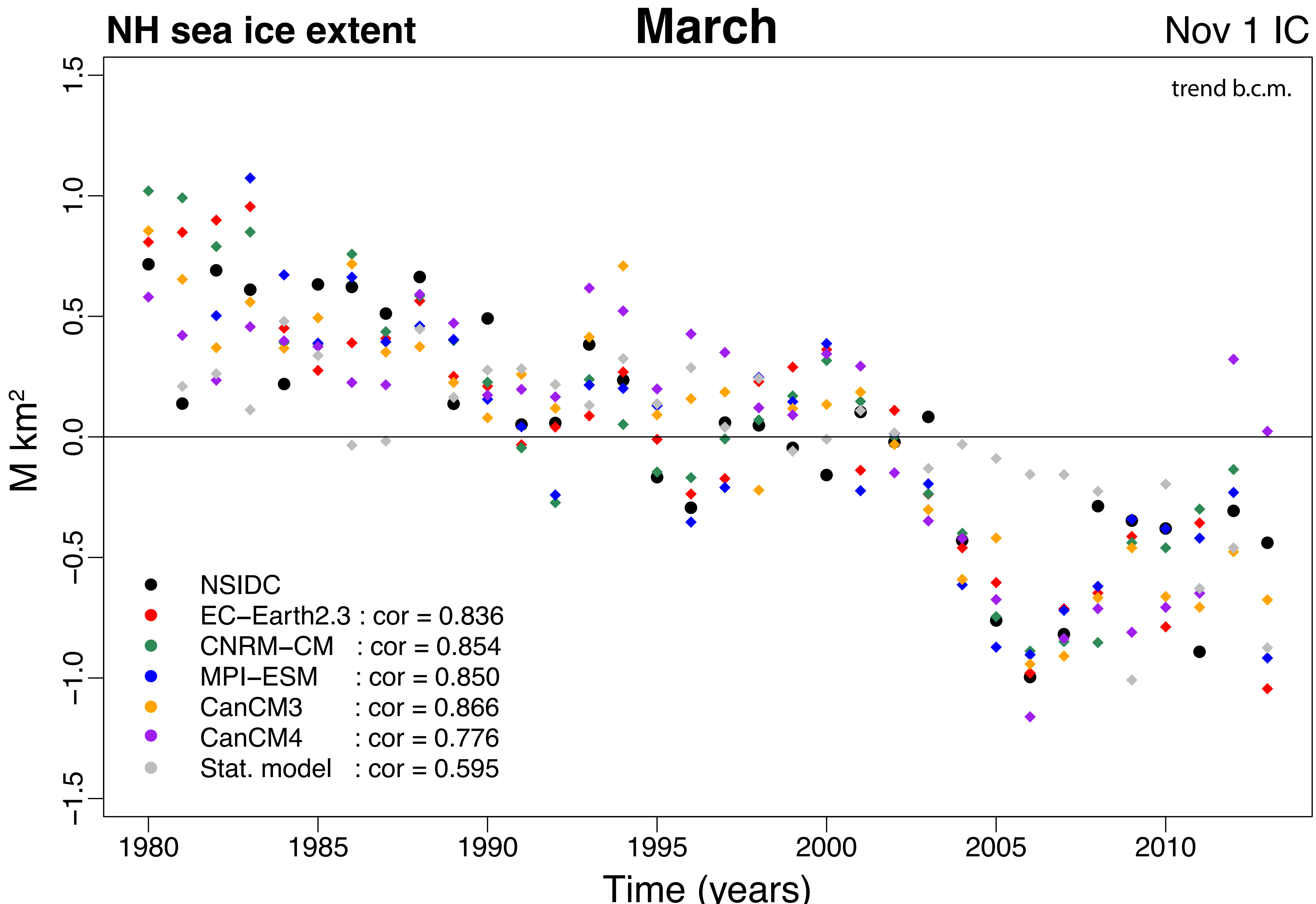
RMSE for NH SIE with Nov 1st IC

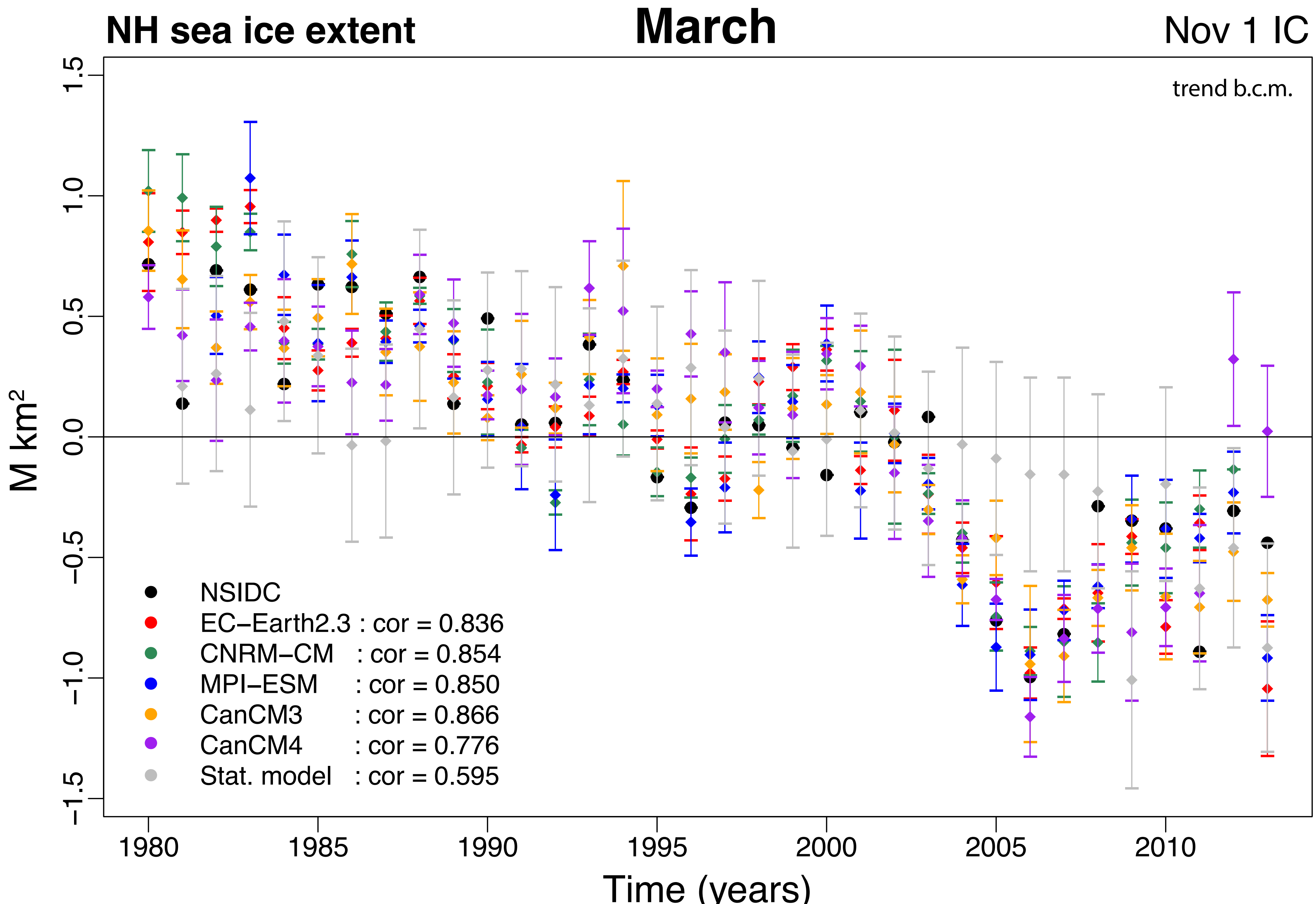


RMSE for NH SIE with May 1st IC



→ **Forecast time (month)**


NH sea ice extent
March
Nov 1 IC
trend b.c.m.
M km2
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
1980
1985
1990
1995
2000
2005
2010
Time (years)
NSIDC
EC−Earth2.3 : cor = 0.836
CNRM−CM : cor = 0.854
MPI−ESM : cor = 0.850
CanCM3 : cor = 0.866
CanCM4 : cor = 0.776
Stat. model : cor = 0.595


NH sea ice extent
March
Nov 1 IC
trend b.c.m.
M km2
Time (years)
NSIDC
EC–Earth2.3 : cor = 0.836
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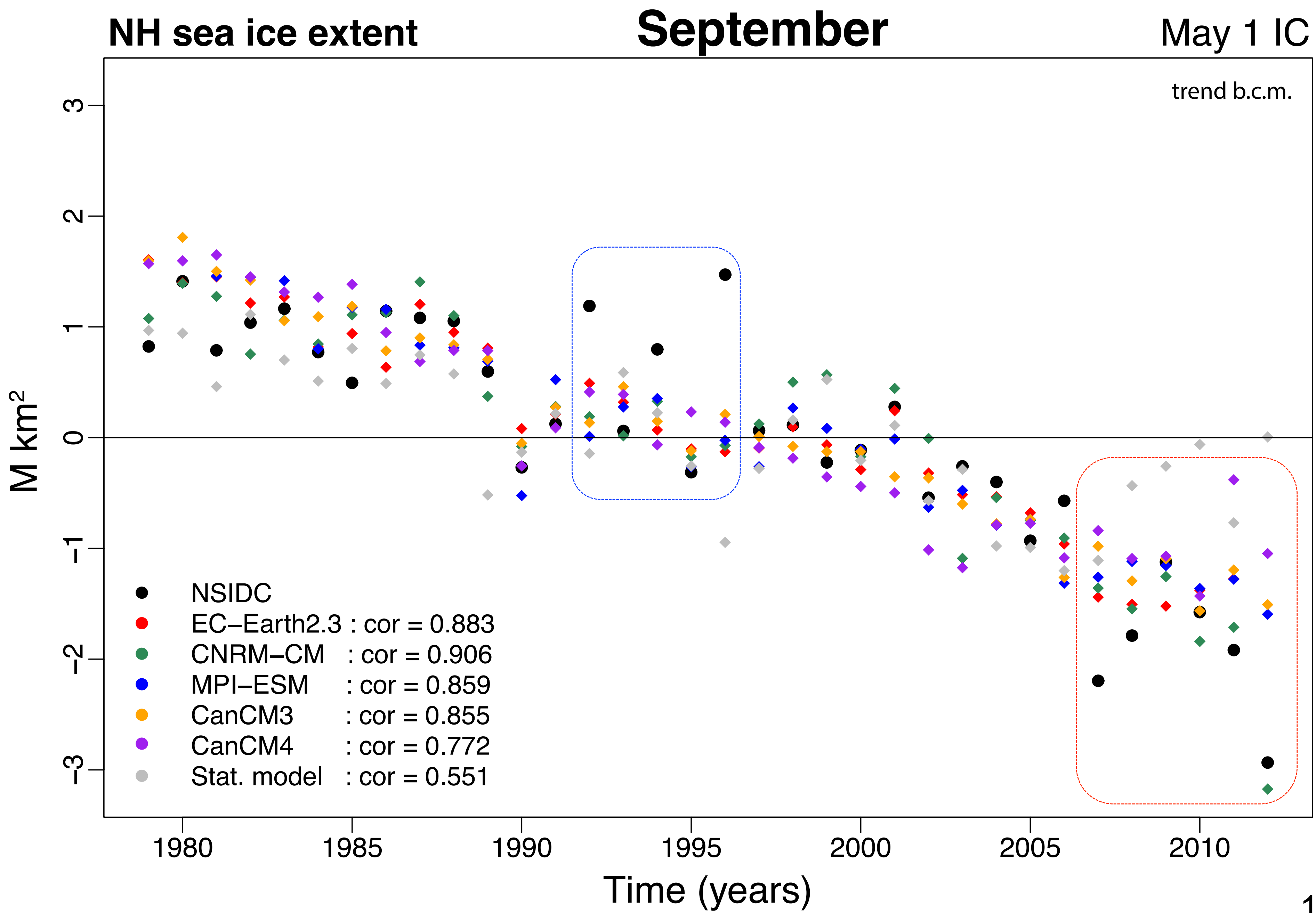
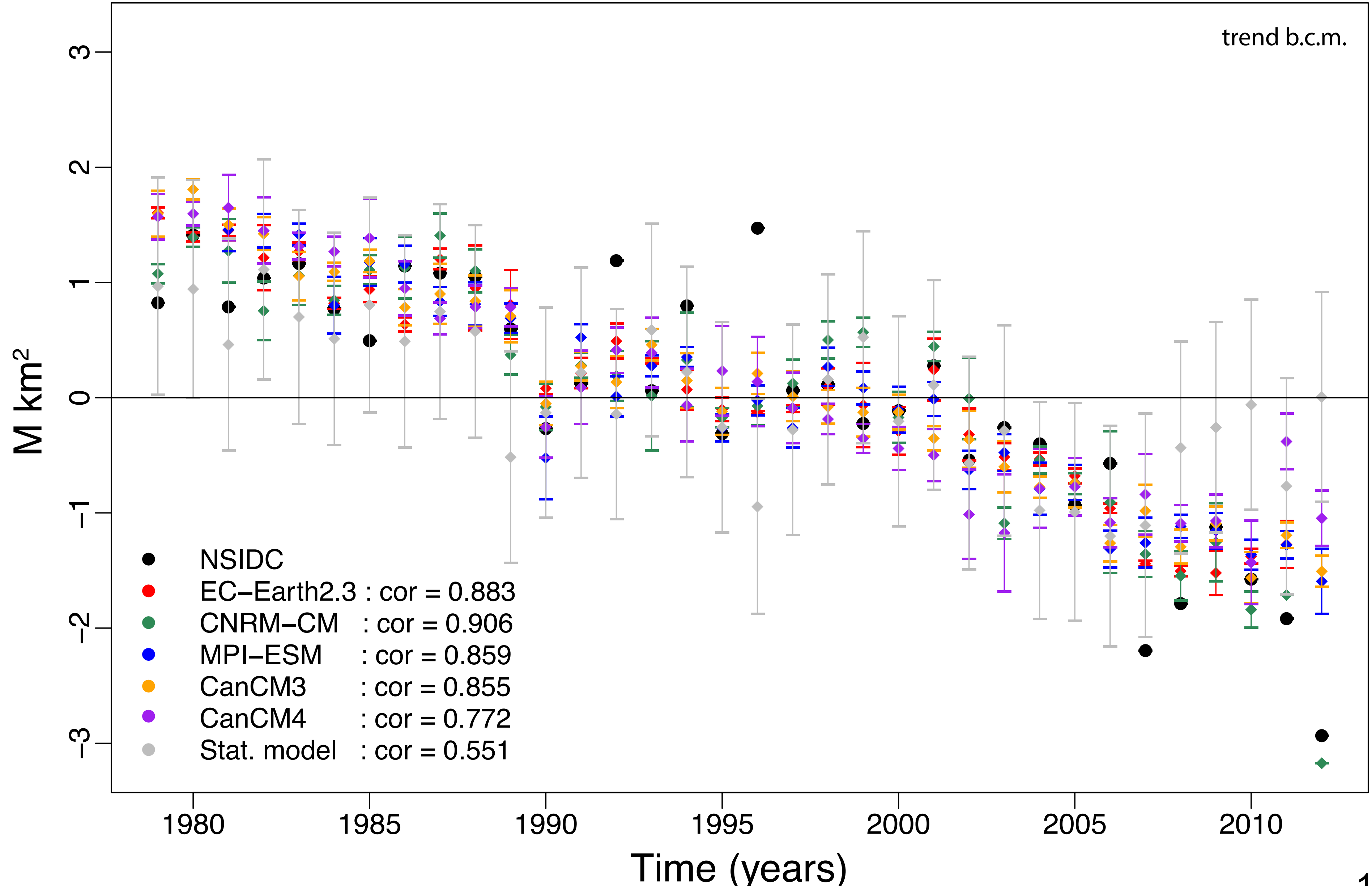
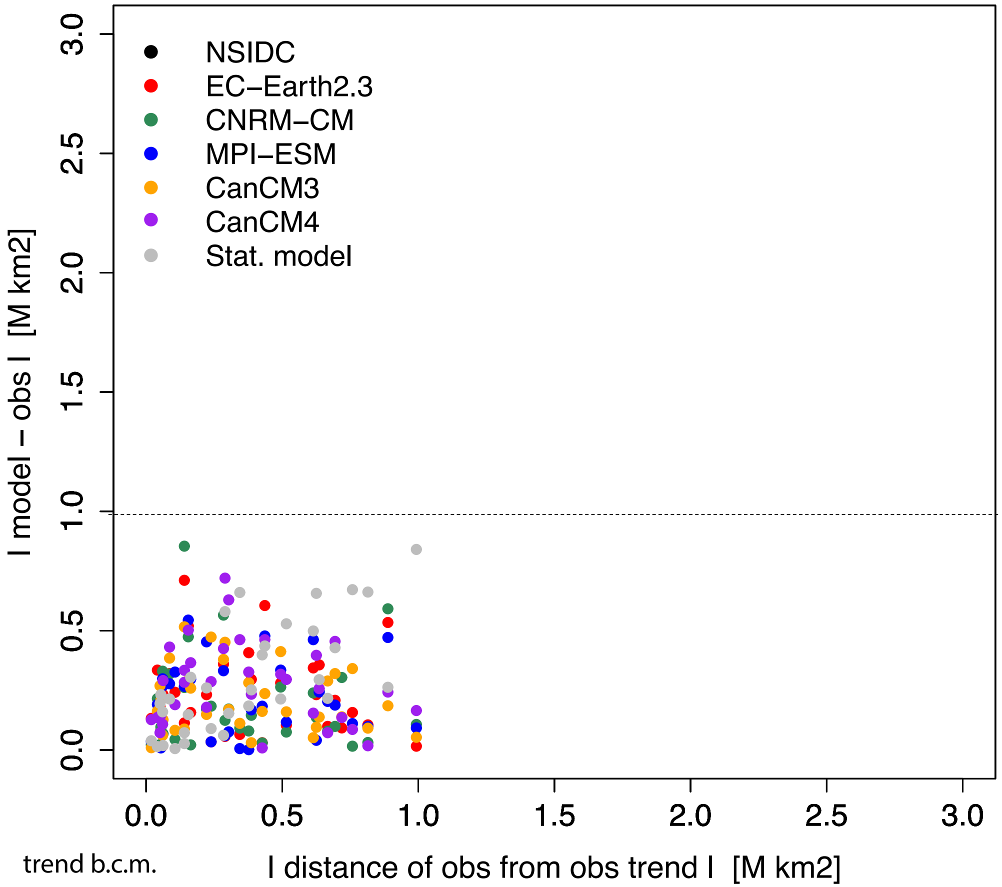

NH sea ice extent
September
May 1 IC
trend b.c.m.
M km²
Time (years)
NSIDC
EC–Earth2.3 : cor = 0.883
CNRM–CM : cor = 0.906
MPI–ESM : cor = 0.859
CanCM3 : cor = 0.855
CanCM4 : cor = 0.772
Stat. model : cor = 0.551
1980
1985
1990
1995
2000
2005
2010
3
2
1
0
−1
−2
−3

NH sea ice extent **September** May 1 IC

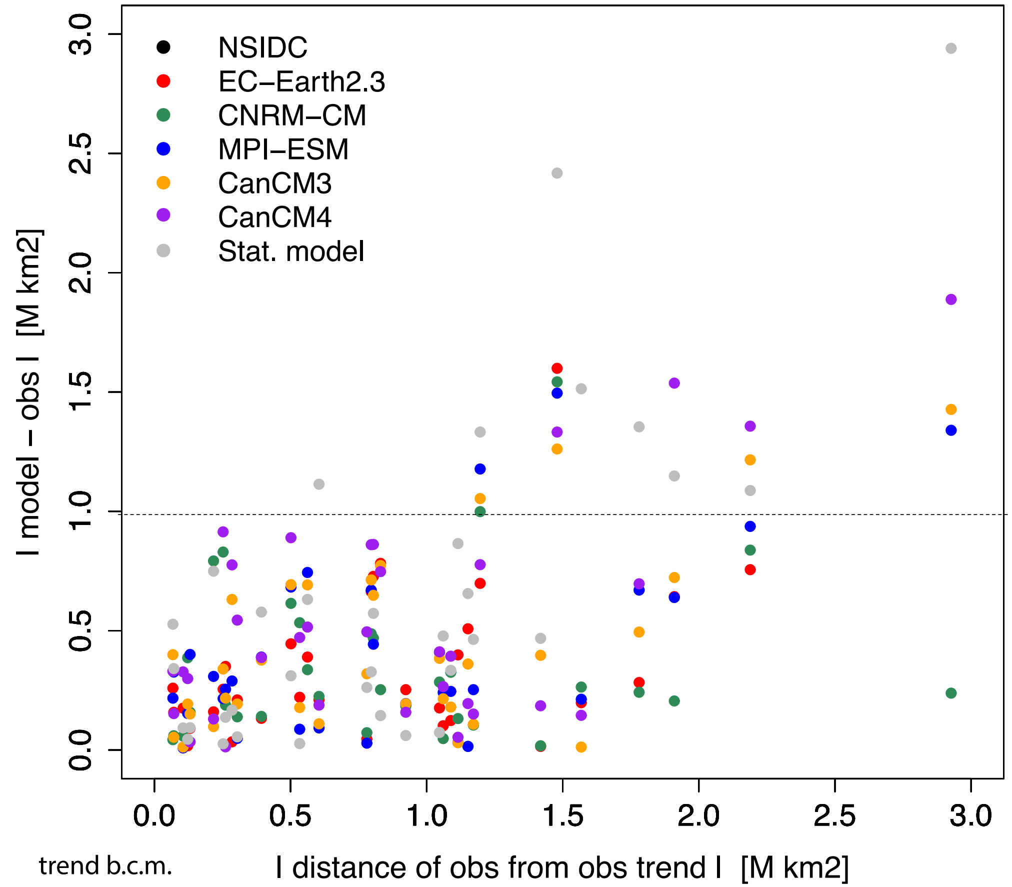


⬆ deviation of Arctic sea ice from obs trend can ⬆ model errors in summer

Ensemble mean errors in March from Nov 1st IC



Ensemble mean errors in September from May 1st IC



⟶ **Absolute distance of NH SIE obs from obs trend (M km^2)**

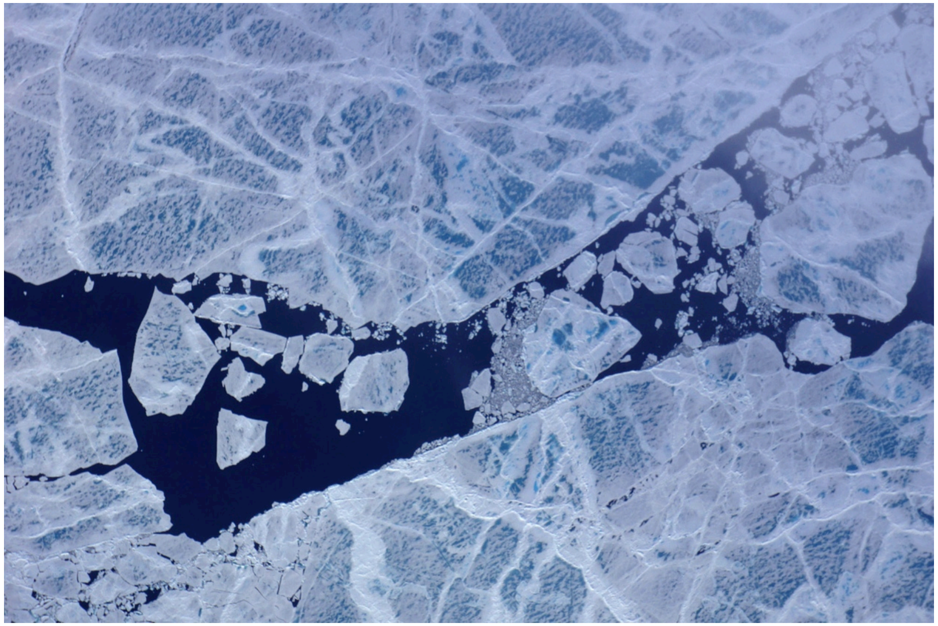
• **Summary** and *future directions*

Bias correction method can have a substantial impact on deterministic prediction skill of the NH sea ice extent

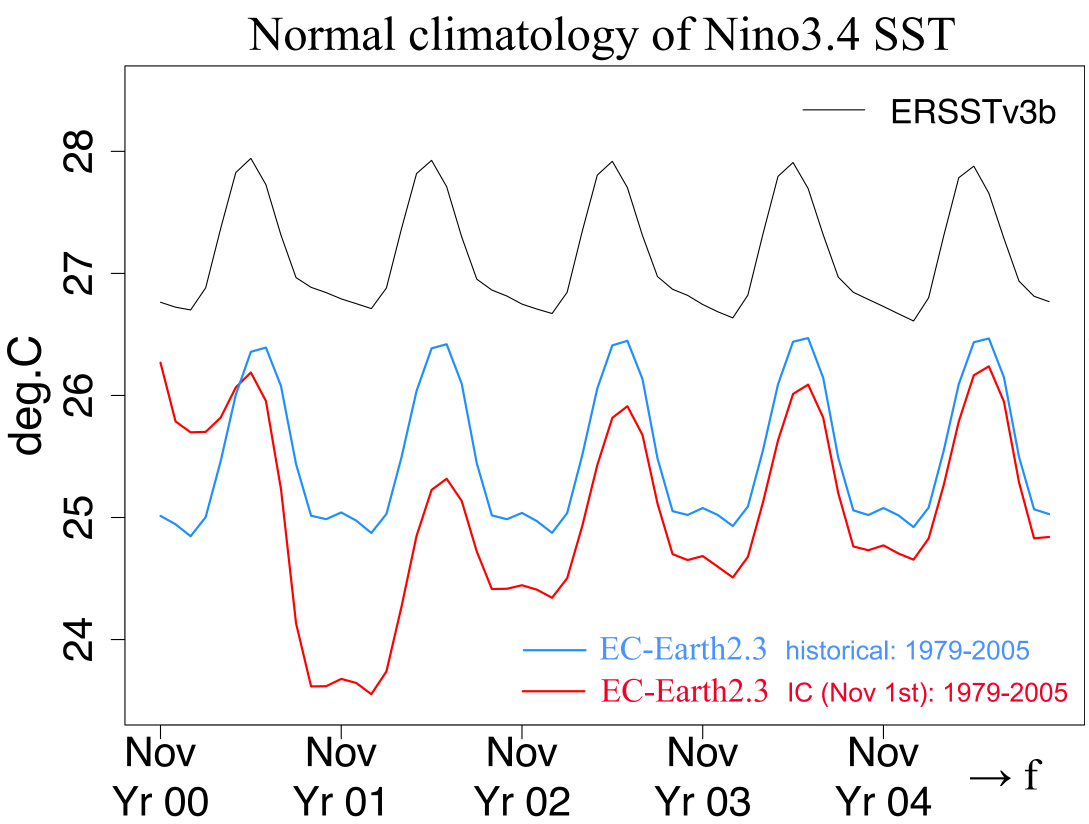
ACC in March and September are similar, while September RMSE is significantly > than March RMSE

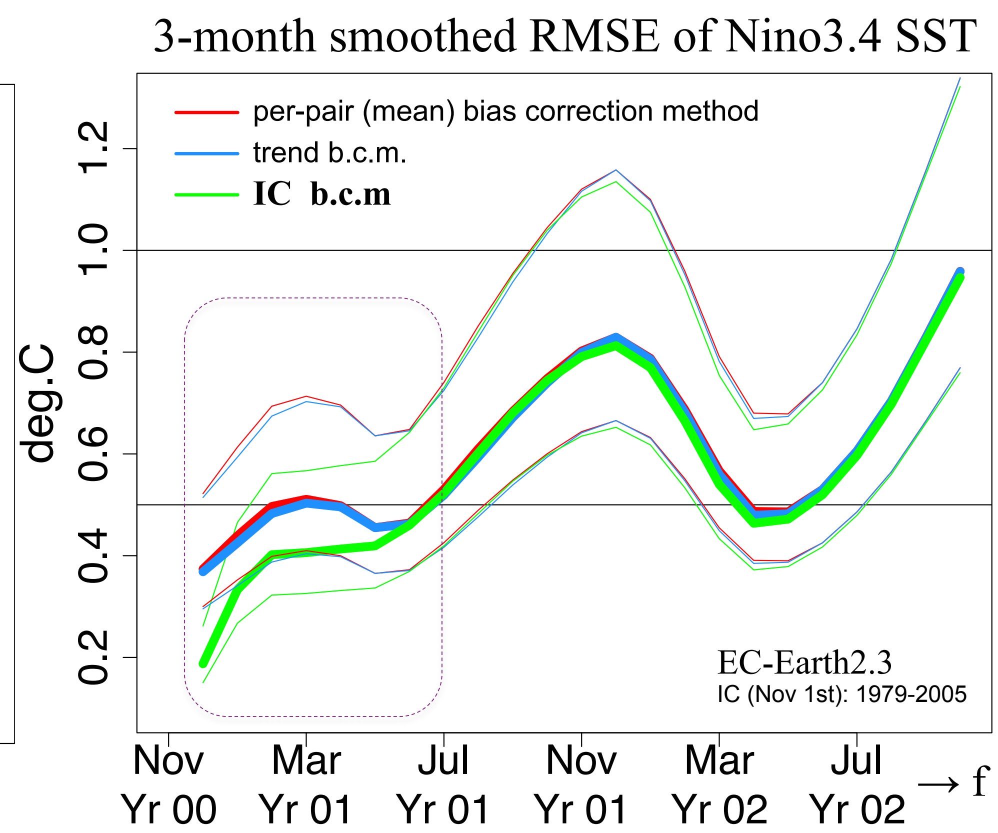
Winter extremes of NH SIE are better predicted than summer extremes that show biggest errors when the Arctic system is far from long-term trend in both positive and negative direction

→ *Analysis of regional skill and its relation to structure of biases in forecast system*



IC bias correction method (Fučkar et al., GRL 2014)





- IC bias correction method replaces the linear regression of monthly forecasts on smoothed proxy of OBS IC, here specifically OBS in the first forecast month $o_{i,1}$, with the linear regression of monthly OBS on $o_{i,1}$ for each forecast month f. *i=start date*